

Report No. 03-68-57

Quarterly Report No. 1

LITHIUM-DIFFUSED SOLAR CELLS

July 1968

**For the Period
1 April 1968—30 June 1968**

Contract No. 952248

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**This work was performed for the Jet Propulsion Laboratory,
California Institute of Technology, as sponsored by the National
Aeronautics and Space Administration under Contract NAS7-100.**

TECHNICAL CONTENT

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ABSTRACT

Recovery data of previously produced lithium-diffused solar cells were analyzed after irradiation with high-energy electrons. These analyses resulted in a change in the type of cell blank used for lithium diffusion. Solar cells were made of two of the three major types of silicon, namely, quartz-crucible, and Lopex.* Electrical characteristics of these cells are presented. Future cells will be fabricated using float-zoned silicon, as well as varied base and doping processes. Also, several samples of lithium-diffused silicon of various resistivities were prepared in a Hall bar configuration and tested.

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I. INTRODUCTION

The objective of the contract is to conduct a program to determine the effects of process parameters upon lithium-diffused solar cell electrical and mechanical characteristics.

II. STATUS OF PREVIOUS LITHIUM CELL RESEARCH

To the extent possible, we have analyzed the recovery data of lithium-diffused solar cells produced under NASA Contract NAS5-10274 after irradiation with high-energy electrons.¹ These cells typically had excellent characteristics before radiation. However, after radiation the following problems were manifest:

- 1) Irradiated cells did not fully recover their pre-irradiation characteristics.
- 2) After a few days of recovery, the cell short circuit current began to degrade.

The incomplete recovery was found to be a function of the area of the cell that was actually diffused with lithium. Details in support of this conclusion are presented in the final report of Contract NAS5-10274.¹ With these facts in mind, we have decided on several changes in the "standard cell" that will be provided under this contract. In the first set of samples lithium will be evaporated onto the back of the cell blank through a larger opening: 15 mils or less along each edge of the cell will be left uncoated, as compared to 30 mils on all previous cells. When the lateral spreading of the lithium during diffusion is taken into account, this will allow the whole cell to be effectively covered.

As discussed in the final report under Contract NAS5-10274 the long term degradation is evidently associated with heavy lithium concentration in the region of the P⁺N junction, probably greater than 10^{17}cm^{-3} . In the central area of the cells provided on the NASA contract, the lithium concentration was generally much less than this. However, since the chemically polished cell blanks were 2 to 4 mils thinner on the edge than in the center, the resulting lithium concentration in a zone near the edge was greater than 10^{17}cm^{-3} . This effect will be minimized under the present program by making the cell thickness more uniform across any given cell.

III. ELECTRICAL PROPERTIES OF LITHIUM-DIFFUSED SILICON

Several samples of lithium-diffused silicon of various resistivities have been prepared using a lithium:tin alloy source. Before lithium diffusion, the silicon samples were phosphorus-doped N-type with resistivities above 100 ohm-cm. These have been fabricated into Hall bars and electrical measurements taken. We have attempted to make both Hall coefficient and lifetime measurements as a function of temperature on several of these samples. The Hall measurements² are shown in Figures 1-4. However, lifetime measurements could not be taken on the samples with the surface photovoltage (SPV) method because the diffusion length was greater than the sample thickness (10

mils). The behavior of the mobility and the carrier concentration over the range of 77° to 300°K is almost identical to that of high-quality arsenic-doped silicon.³ In view of the different mode of incorporation of lithium (interstitial instead of substitutional), this is not an obvious result. Note also the similarity between the lithium-diffused samples containing oxygen (quartz-crucible QC) and those containing much less of this impurity (Lopex L). This is especially evident in samples 75L and 81QC, where a common line has been drawn through the carrier concentration, Hall coefficient, resistivity, and mobility data.

IV. STANDARD CELL FABRICATION

During the first portion of this contract we are making lithium-diffused solar cells from the three major types of silicon, namely, quartz-crucible QC, Lopex L, and float-zoned FZ. As discussed in Section II, we are using the experience from a previous contract as a guide. Thus these cells are made from optically polished cell blanks (rather than chemically polished) and the lithium evaporation is undertaken through a larger mask than previously used. Lots 1 and 2 were fabricated identically (1.5 hours at 400°C for the lithium diffusion) using quartz-crucible material, except an additional 2 hours of diffusion at 400°C (after removing the evaporated lithium) was given the 60 cells of Lot 2. Lots 3 and 4 will be diffused for 1.5 hours at 400°C into Lopex and float-zoned silicon, respectively, with neither group receiving the additional "redistribution" cycle. However, all of the cells will be sintered for 3 minutes after the contacts are applied. This treatment is equivalent to a redistribution of about one hour at 400°C.

The electrical characteristics of each of the cells in Lots 1 and 2 are shown in Tables I, II, and III. The light source was tungsten of 100 mW/cm² and was calibrated on N on P solar cells, so the absolute values may not be accurate.

V. WORK PLANNED

The next two lots will be fabricated in the same manner as Lot 1, except the base material will be greater than 50 ohm-cm phosphorus-doped Lopex and float-zoned silicon. We also expect to fabricate some cells using a tin-lithium alloy in the latter part of the second quarter.

VI. NEW TECHNOLOGY

No reportable items of new technology have been identified during this report period.

VII. REFERENCES

1. Don L. Kendall and R. A. Vineyard, Final Report, Contract NAS5-10274(1968) Texas Instruments Incorporated.
2. Hall measurements taken by Gregg Lee.
3. N. B. Hannay, *Semiconductors* (New York: Reinhold, 1959), pp. 35, 38, 39, 359; F. J. Morin and J. P. Maita, *Phys. Rev.*, 96, 28 (1954).

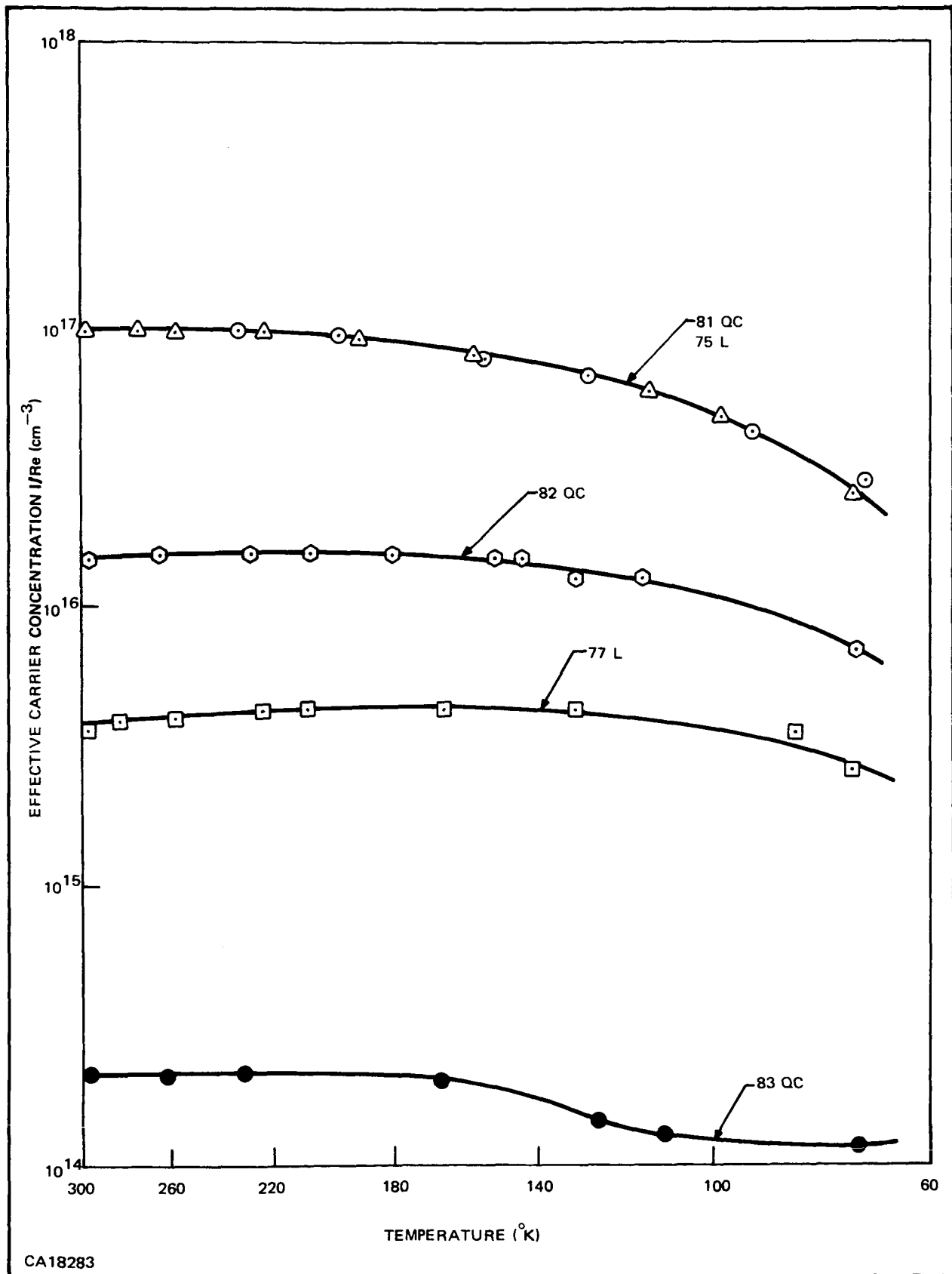


Figure 1. Carrier Concentration vs Temperature for Lithium-Diffused Silicon

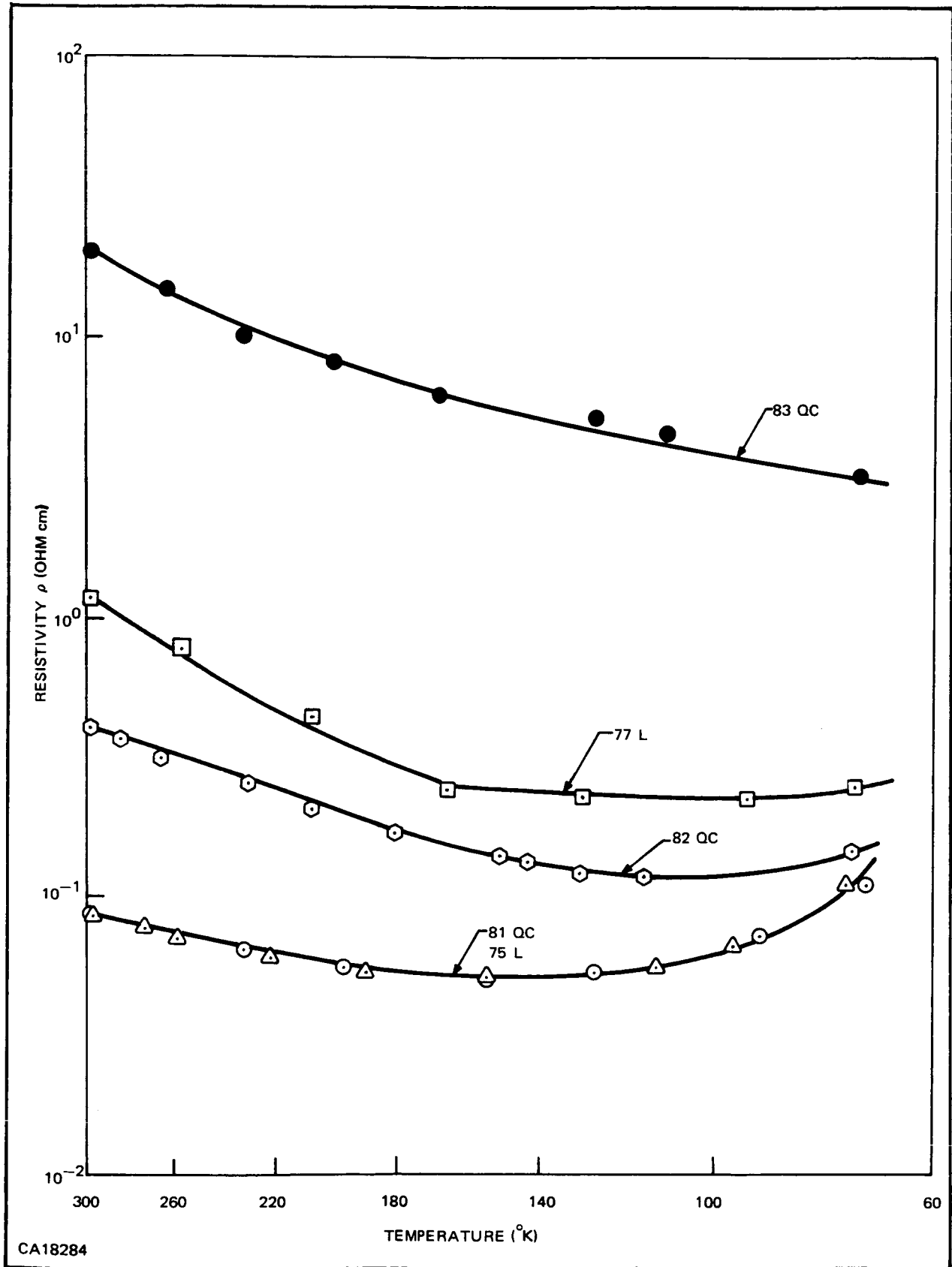


Figure 2. Resistivity vs Temperature for Lithium-Diffused Silicon

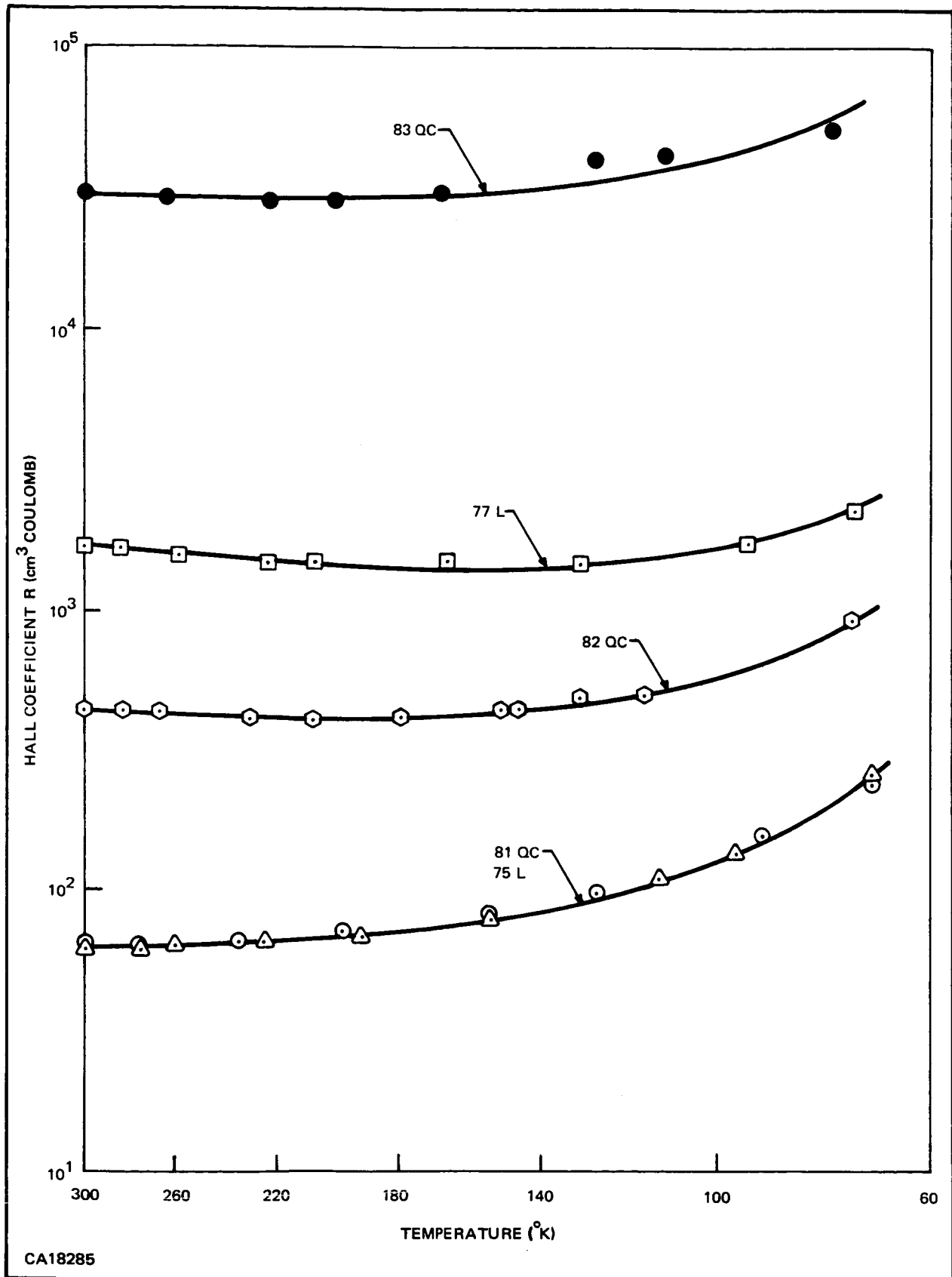


Figure 3. Hall Coefficient vs Temperature for Lithium-Diffused Silicon

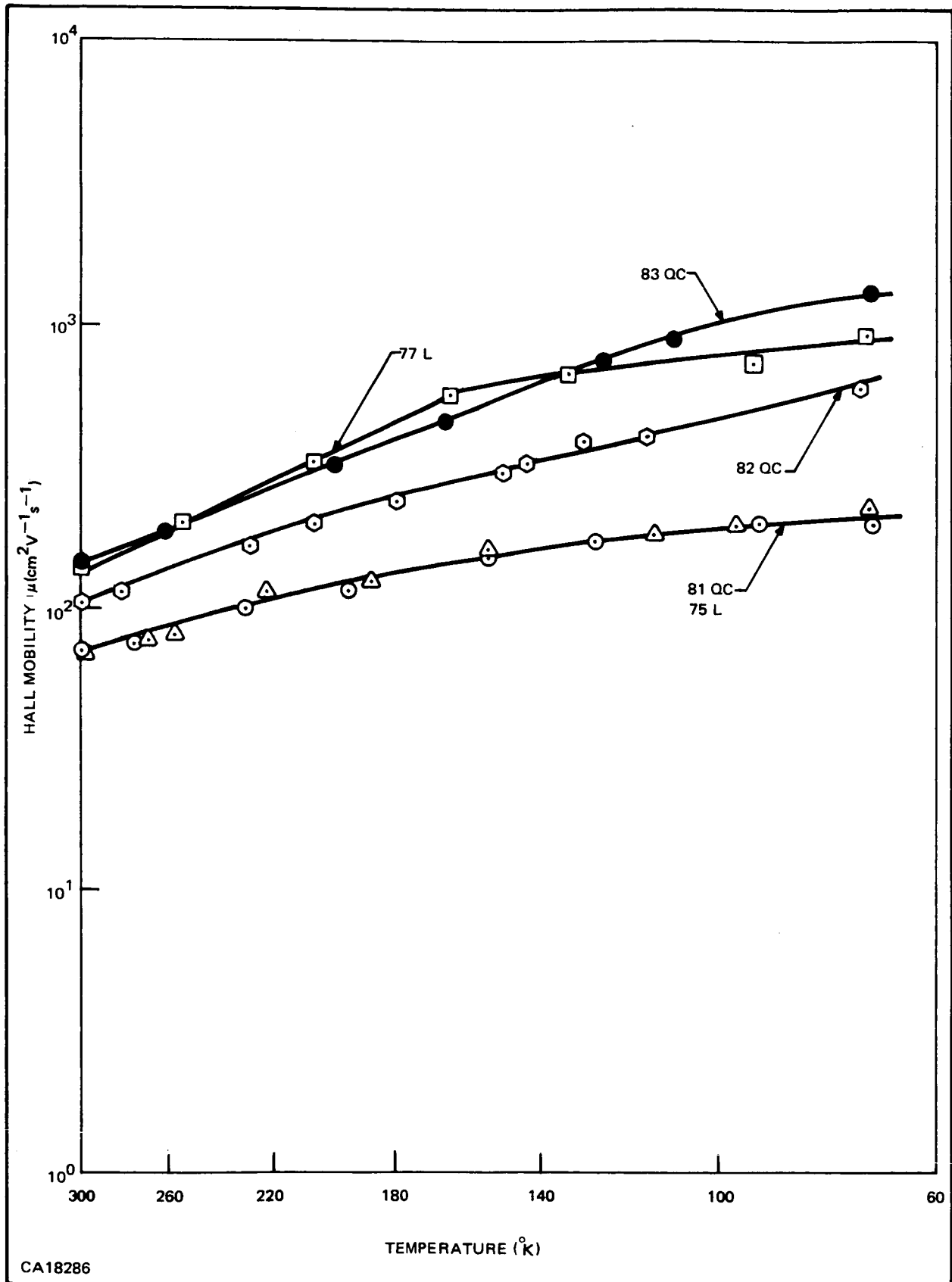


Figure 4. Mobility vs Temperature for Lithium-Diffused Silicon

Table I. Cell Characteristics of Lot 1B*
(90-minute Diffusion at 400°C into QC Silicon)

Cell No.	I _{SC} (mA)	I _{0.430 V} (mA)	V _{OC} (V)	Cell No.	I _{SC} (mA)	I _{0.430 V} (mA)	V _{OC} (V)
T1-1B	58.0	55.0	0.600	T1-21B	54.8	45.8	0.582
T1-2B	57.5	53.8	0.600	T1-22B	56.2	47.0	0.590
T1-3B	55.8	53.3	0.600	T1-23B	57.5	53.0	0.590
T1-4B	56.5	53.8	0.600	T1-24B	55.0	47.0	0.585
T1-5B	56.5	53.5	0.600	T1-25B	57.2	49.8	0.588
T1-6B	56.5	53.5	0.605	T1-26B	55.3	49.5	0.590
T1-7B	57.5	53.0	0.596	T1-27B	54.4	48.0	0.588
T1-8B	58.0	53.9	0.590	T1-28B	53.8	48.5	0.589
T1-9B	57.2	53.0	0.592	T1-29B	55.0	47.0	0.580
T1-10B	55.2	53.3	0.605	T1-30B	55.0	48.5	0.585
T1-11B	57.0	52.0	0.590	T1-31B	56.5	49.2	0.589
T1-12B	56.6	51.0	0.596	T1-32B	54.5	49.2	0.590
T1-13B	56.2	51.0	0.595	T1-33B	56.2	49.6	0.589
T1-14B	55.2	51.0	0.594	T1-34B	55.2	50.4	0.590
T1-15B	55.0	51.4	0.595				
T1-16B	55.1	52.0	0.598				
T1-17B	54.5	51.8	0.600				
T1-18B	54.5	52.0	0.600	Avg.	55.8	50.7	0.592
T1-19B	55.1	48.5	0.585	Low	53.8	45.5	0.578
T1-20B	53.8	45.5	0.578	High	58.0	55.0	0.605

*NOTE: Lot 1 (cells 1-34) sent to NASA Goddard by mistake.

These are replacements.

**Table II. Cell Characteristics of Lot 1, Cells 36-61
(90-minute Diffusion at 400°C into QC Silicon)**

Cell No.	I _{SC} (mA)	I _{0.430 V} (mA)	V _{OC} (V)	Cell No.	I _{SC} (mA)	I _{0.430 V} (mA)	V _{OC} (V)
T1-36	59.8	54.0	0.590	T1-52	54.0	51.2	0.592
T1-37	59.1	56.0	0.600	T1-53	54.0	51.2	0.600
T1-38	57.0	51.0	0.590	T1-54	54.0	50.3	0.585
T1-39	57.4	53.0	0.588	T1-55	54.0	51.8	0.599
T1-40	56.2	51.9	0.590	T1-56	53.8	51.3	0.590
T1-41	56.0	52.1	0.590	T1-57	53.5	49.8	0.585
T1-42	53.6	50.3	0.590	T1-58	53.8	49.9	0.592
T1-43	57.8	54.8	0.592	T1-59	53.9	49.0	0.592
T1-44	55.5	50.2	0.589	T1-60	52.8	49.0	0.590
T1-45	56.0	53.0	0.590	T1-61	53.0	49.0	0.590
T1-46	57.2	50.0	0.582				
T1-47	55.0	49.0	0.580				
T1-48	54.0	50.0	0.585				
T1-49	53.8	50.0	0.585	Avg.	55.2	51.2	0.590
T1-50	54.2	50.8	0.589	Low	52.8	49.0	0.580
T1-51	55.5	52.2	0.589	High	59.8	56.0	0.600

Table III. Cell Characteristics of Lot 2
(90-minute Diffusion at 400°C
Followed by a 2 Hour Redistribution at 400°C into QC Silicon)

Cell No.	I _{SC} (mA)	I _{0.430 V} (mA)	V _{OC} (V)	Cell No.	I _{SC} (mA)	I _{0.430 V} (mA)	V _{OC} (V)
T2-1	59.1	53.2	0.580	T2-34	54.2	49.0	0.580
T2-2	58.3	51.5	0.575	T2-35	56.8	49.1	0.572
T2-3	58.3	52.2	0.580	T2-36	57.0	49.2	0.570
T2-4	57.0	50.8	0.578	T2-37	59.0	50.0	0.562
T2-5	58.2	52.0	0.579	T2-38	58.1	49.1	0.574
T2-6	58.0	52.2	0.580	T2-39	57.7	49.8	0.578
T2-7	56.6	52.0	0.582	T2-40	55.2	46.8	0.570
T2-8	56.8	51.2	0.578	T2-41	57.0	49.8	0.570
T2-9	58.0	51.9	0.575	T2-42	59.3	47.0	0.570
T2-10	59.3	52.0	0.576	T2-43	56.8	50.3	0.570
T2-11	57.8	51.8	0.576	T2-44	55.0	48.5	0.565
T2-12	57.8	51.9	0.574	T2-45	58.5	48.7	0.578
T2-13	59.0	51.8	0.572	T2-46	57.0	48.5	0.570
T2-14	58.2	51.7	0.580	T2-47	57.2	50.2	0.578
T2-15	59.2	52.5	0.572	T2-48	56.0	48.0	0.565
T2-16	57.0	51.3	0.579	T2-49	56.9	47.0	0.573
T2-17	56.5	50.6	0.578	T2-50	55.5	47.2	0.570
T2-18	58.5	50.5	0.570	T2-51	57.0	47.0	0.562
T2-19	57.0	47.5	0.570	T2-52	57.0	47.0	0.575
T2-20	56.2	51.0	0.580	T2-53	56.5	45.8	0.558
T2-21	57.0	51.0	0.570	T2-54	54.9	46.8	0.564
T2-22	56.1	51.2	0.584	T2-55	55.9	46.0	0.558
T2-23	56.8	51.0	0.572	T2-56	59.0	45.9	0.582
T2-24	56.0	48.2	0.570	T2-57	58.9	50.0	0.575
T2-25	57.8	50.8	0.574	T2-58	54.8	47.0	0.570
T2-26	56.8	50.0	0.578	T2-59	56.2	48.0	0.575
T2-27	55.0	49.2	0.570	T2-60	57.2	49.6	0.578
T2-28	56.2	49.8	0.578				
T2-29	58.0	50.8	0.570				
T2-30	57.9	50.0	0.568				
T2-31	58.6	50.9	0.573	Avg.	57.2	49.9	0.564
T2-32	57.5	50.0	0.580	Low	55.0	45.8	0.562
T2-33	56.2	48.2	0.573	High	59.3	53.2	0.584